XLIX. *Deſcription of a Method of meaſuring Differences of Right Aſcenſion and Declination, with* Dollond's *Micrometer, together with other new Applications of the ſame: By the Rev.* Nevil Maſkelyne, *B. D. F. R. S. Aſtronomer Royal.*

Read Dec. 12, 1771. THE divided object glaſs micrometer, as happily applied by the late Mr. John Dollond to the object end of a reflecting teleſcope, and now with equal advantage adapted by the preſent Mr. Dollond, his ſon, to the end of an achromatic teleſcope, is ſo eaſy of uſe, and affords ſo large a ſcale, that it is generally looked upon by aſtronomers as the moſt convenient and exact inſtrument for meaſuring ſmall diſtances in the heavens. But, as the common wire micrometer is peculiarly adapted for meaſuring differences of right aſcenſion and declination of celeſtial objects, and is not near ſo convenient or exact for meaſuring their abſolute diſtances; ſo on the contrary the object glaſs micrometer is peculiarly fitted for meaſuring diſtances, and has, I believe, generally been ſuppoſed incapable of or unfit for meaſuring differences of right aſcenſion and declination. Thus the two micrometers, as mutually ſupplying each other's defects, have been eſteemed both

both equally neceſſary in their turn to be uſed by the practical Aſtronomer, and conſequently to have a place in every well-furniſhed Obſervatory. Far be it from me to ſay any thing to the diſparagement of either of theſe valuable inſtruments, or to envy it the place which it is ſo juſtly entitled to. Every Aſtronomer, who has time and inclination for making a variety of obſervations, would undoubtedly wiſh to be ſupplied with, and to make uſe of both. But, as every perſon deſirous of making obſervations for his own amuſement or public utility may not happen actually to be furniſhed with, nor chuſe to be at the expence of providing himſelf with both, it is certainly a very deſirable thing, if he could be enabled to make that uſe of the inſtrument he has, which might ſupply, in ſome meaſure at leaſt, the want of the other which he has not. Therefore, as I find that the object-glaſs micrometer may be applied with little trouble and but ſmall additional expence to the meaſuring differences of right aſcenſion and declination, with an exactneſs little, if at all, inferior to what they can be obtained with the common micrometer, I propoſe to give here the directions neceſſary to be followed when it is uſed in this manner. I ſhall afterwards ſhew how differences of right aſcenſion and declination between the limbs of the Sun and Venus or Mercury, and diſtances of the limbs both in lines parallel and perpendicular to the equator, may alſo be obſerved in the tranſits of theſe planets over the Sun. Examples of the ſecond and third of theſe methods may be ſeen in the obſervations of the late tranſit of Venus at the North Cape, and in the South Seas, made according to theſe di-

rections, which were previouſly communicated to the obſervers.

A ſmall addition will be neceſſary to be made to the apparatus of the object-glaſs micrometer, to enable it to anſwer theſe purpoſes, viz. a cell, containing two wires interſecting each other at right angles, placed in the focus of the eye-glaſs of the teleſcope, and moveable round about, by the turning of a button. Let E N W S, TAB. XVI. Fig. 1. repreſent the field-bar of the teleſcope, E W and N S two wires interſecting each other at right angles at C, and moveable about the ſame as a center, in manner above-mentioned. Suppoſe it be required to meaſure the difference of right aſcenſion and declination of two ſtars, whoſe difference of declination does not exceed the extent of the ſcale of the micrometer, and the diſtance of the meridians paſſing through the ſtars does not exceed C W, the ſemidiameter of the field of the teleſcope. Turn the wires E W, N S about, till one of the ſtars (the weſternmoſt ſtar will generally be beſt for this purpoſe) runs exactly along the wire E W, by the diurnal motion. Then ſeparate the two ſegments of the divided object-glaſs to a convenient diſtance, and turn the micrometer round about, by means of the proper handle, till the two images of the ſame ſtar, formed by the two ſegments of the object-glaſs, paſs the horary wire N S at the ſame inſtant. Laſtly, partly by ſeparating the glaſſes, and partly by touching the rack-work ſcrews of the ſtand of the teleſcope, cauſe the ſouthernmoſt image of the northernmoſt ſtar, and the northernmoſt image of the ſouthernmoſt ſtar, to appear both upon and run along the wire E W, as A, B. The numbers ſtanding upon the ſcale

of

Fig. I.

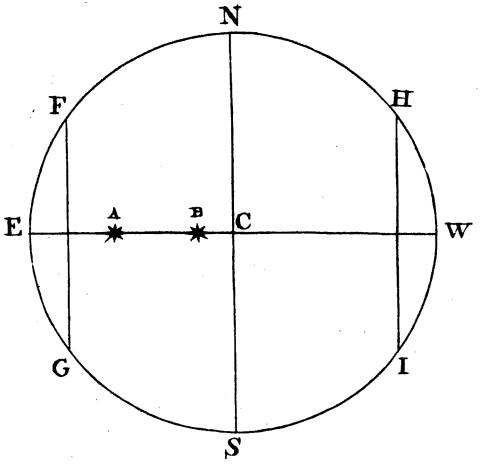


Fig. II.

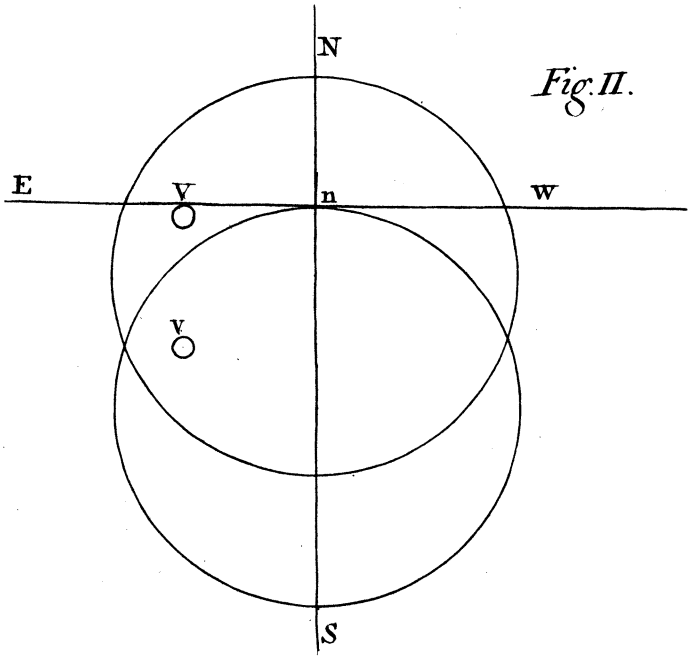


Fig. III.

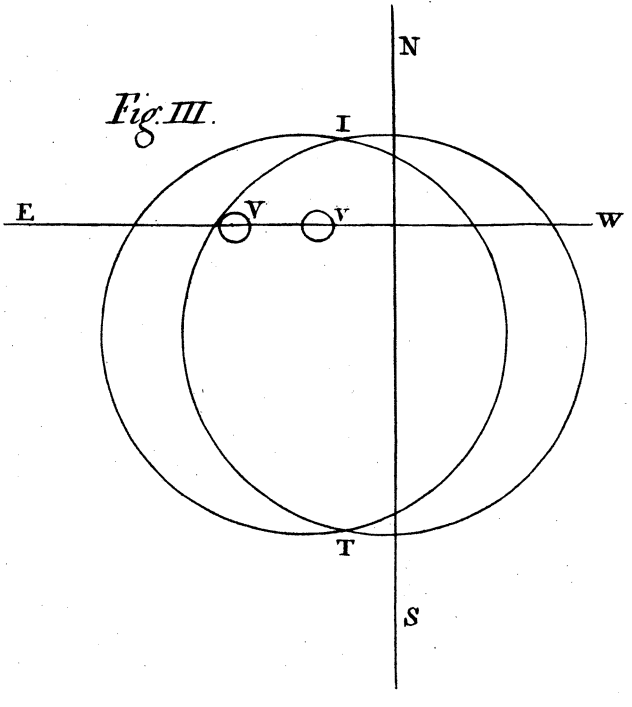
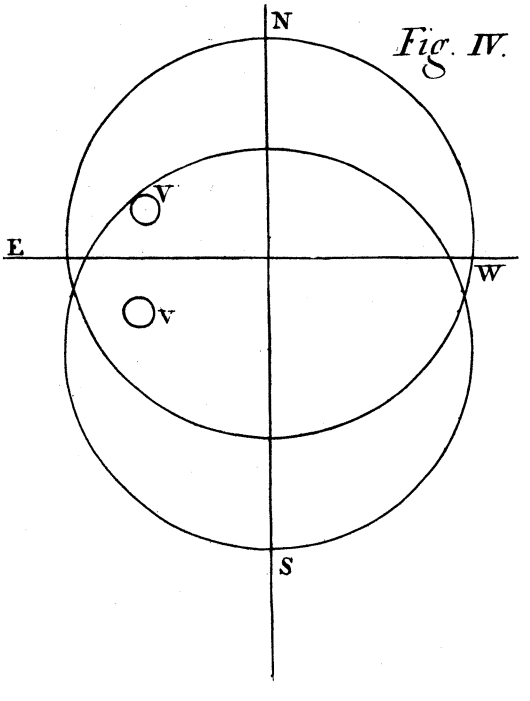


Fig. IV.



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of the micrometer will ſhew the difference of declination of the ſtars; and if the times be noted when they paſs the horary wire N S the difference of the times will give the difference of their right aſcenſion. For E W on account of the ſtar's running along it, is parallel to the equator; and conſequently N S which is perpendicular to it, repreſents a meridian or horary circle. And becauſe the two images of the ſame ſtar paſs the horary wire N S at the ſame inſtant, it follows that the centres of the two ſemicircular glaſſes lie in the ſame meridian, and conſequently when A, B, the two contrary images of the two ſtars are brought to the ſame parallel of declination E W, the ſcale will ſhew the difference of their declinations. And, for the ſame reaſon, the times of the images of the two ſtars paſſing the meridian wire N S will not be affected by the ſeparation of the glaſſes of the micrometer, and conſequently the difference of the times will give the difference of their right aſcenſion. It will be eaſily underſtood that in performing the operations above deſcribed, it will be neceſſary from time to time to turn the ſcrews of the rack-work which move the whole teleſcope together. Theſe operations will be much facilitated and rendered more exact, if the teleſcope be ſupported by and moveable on a polar axis; for the wires and micrometer may be thereby more readily brought into the requiſite poſitions, and the turning of the teleſcope about in order to follow the diurnal motion will not diſturb thoſe poſitions; which will afford this farther advantage to the obſerver, of being able to repeat the obſervations without loſs of time.

If two additional horary wires F G, H I parallel to N S be placed near E and W the two extremi-

ties of the wire, E W the adjuſtment of the wires and micrometer may be more readily performed, and the obſervation may be made on two ſtars, although their meridian diſtance from one another ſhould be almoſt equal to E W the diameter of the field of the teleſcope. It is evident, that if two ſtars be thus obſerved whoſe difference of declination is well ſettled, the value of the ſcale of the micrometer may be thereby determined.

In the foregoing directions it has been ſuppoſed that the images of the two ſtars can be brought to appear within the field of the teleſcope on the wire E W at the ſame time; but this is not abſolutely neceſſary. For if the micrometer be ſet to the difference of declination nearly, and then the ſtar which paſſes firſt through the teleſcope be made to run along the wire E W by touching one of the handles of the rack-work of the teleſcope, and afterwards the other ſtar, when it comes into the teleſcope, be brought to the wire E W by altering the opening of the glaſſes of the micrometer, the difference of the declination will be had, by taking half the ſum of the numbers ſhewn by the micrometer, at the two ſeparate obſervations of the two ſtars on the wire E W. This will be true, in caſe it can be depended upon that the two ſemicircular glaſſes recede equally in contrary directions; which may indeed be doubted, the work on which the motion of the glaſſes depends not being deſigned for ſuch a purpoſe, and therefore probably not made ſufficiently accurate for it.

The manner in which Mr. Dollond has contrived the motion of the glaſſes in his new improvement of the object-glaſs micrometer intirely obviates this difficulty,

difficulty, and the difference of right aſcenſion and declination of any two ſtars or other points in the heavens may be thereby accurately meaſured, let the difference of right aſcenſion be what it will, provided the difference of declination does not exceed the extent of the ſcale of the micrometer; and thus the object-glaſs micrometer is put pretty much on a footing with the common micrometer, even with reſpect to the meaſuring right aſcenſions and declinations.

The difference of right aſcenſion and declination between Venus or Mercury and the Sun's limb, in their tranſits over the Sun, are to be obſerved nearly in the ſame manner as the difference of right aſcenſion and declination of two ſtars. But the proceſs will perhaps be rendered clearer by the following deſcription.

1. Turn the moveable wires E W, N S, into ſuch a poſition that the Sun's North limb *n* (ſee fig. II.) or the planets North limb V may run along the wire E W, which thereby becomes a tangent to the peripheries of their diſcs.

2. The ſemicircular glaſſes being ſeparated to a convenient diſtance, turn the micrometer about, till the two images of the planet V, *v*, paſs over the horary wire N S at the ſame inſtant.

3. Separate the glaſſes of the micrometer to that diſtance, that the North limb V of the Northernmoſt image of the planet may touch the wire E W at the ſame time that the Northernmoſt limb *n* of the Southernmoſt image of the Sun touches the ſame wire; and the ſcale of the micrometer will ſhew the difference of declination of the Northern limbs of the

the Sun and planet. In like manner, if the glaſſes of the micrometer be opened to a greater or leſs diſtance (according as the planet is nearer the North or South limb of the Sun) every thing elſe remaining unmoved, the difference of declination of the Southern limbs of the Sun and planet may be obſerved, by bringing the Southernmoſt limb of the Southernmoſt image of the planet to run along the wire EW, at the ſame time that the Southernmoſt limb of the Northernmoſt image of the Sun runs along the ſame. Half the difference of theſe two meaſures (if taken immediately after one another) is equal to the difference of the declination of the centers of the Sun and planet at the intermediate time, without any regard to the quantities of the diameters of the Sun or planet, or the error of adjuſtment of the micrometer.

The difference of the tranſits of the Eaſtern or Weſtern limbs of the Sun and planet will give the difference of right aſcenſion, as in the common micrometer.

Inſtead of differences of right aſcenſion, diſtances of the planet from the Sun's limb in lines parallel to the equator may be more accurately obſerved as follows.

The glaſſes being ſeparated to a convenient diſtance, turn both the wires and micrometer about, ſo that the two images of the planet may both run along the wire E W (ſee Fig. III.) and ſeparate the glaſſes, ſo that V one of the images of the planet may touch the limb of the Sun to the Eaſt or Weſt, or rather both alternately. Or perhaps the following method may be preferable: ſeparate the two images of the Sun to any convenient diſtance, ſo as to produce a conſiderable angle of interſection of the circumferences at I and T;

Turn the wires about, ſo that the planet's centre, North, or South limb, may run along the wire E W; Then turn the micrometer about till the two interſections I T paſs the horary wire N S at the ſame inſtant, and the micrometer will be in a proper poſition for meaſuring diſtances in a line parallel to the equator; and the diſtance of the planet from the Sun's limb in a line parallel to the equator will be obtained by only bringing the glaſſes nearer together, or ſeparating them farther, till the planet's limb is in contact with the Sun's limb. If diſtances of the planet's near limb from the Sun's limb be thus taken to the Eaſt and Weſt alternately, and reduced to a given time, by allowing for the motion of the planet by calculation, half the difference of the two reduced meaſures will be the diſtance of the planet's centre from the middle of the chord of the Sun's diſc paſſing through the planet's centre parallel to the equator at the given time, without any regard to the quantities of the diameters of the Sun or planet, or the error of the adjuſtment of the micrometer. It may be proper to remark, that when the planet is brought to touch the Sun's limb, the point of contact will be North or South of the planet's centre according as the planet itſelf is North or South of the Sun's centre.

In like manner, diſtances of Venus or Mercury from the Sun's limb may be meaſured in lines perpendicular to the equator, ſee Fig. IV. (the micrometer being brought into the proper poſition, in the very ſame manner as for meaſuring the difference of declination from the Sun's north or ſouth limb, before deſcribed); and if the planet be brought into contact with

with the Sun's limb to the north and ſouth alternately, half the difference of the two meaſures, reduced to a given time by allowing for the motion of the planet by calculation, will be the difference of declination of the centers of the Sun and planet at that time, without any regard to the diameters of the Sun or planet, or the error of adjuſtment of the micrometer. And this would be a better obſervation than meaſuring the difference of declination of the limbs of the Sun and planet by bringing them both in contact with the ſame wire parallel to the equator deſcribed above; as the meaſuring diſtances from the Sun's eaſt or weſt limb in lines parallel to the equator is a better obſervation than meaſuring differences of right aſcenſion of the limbs by time.

By theſe two obſervations of diſtances of an inferior planet from the Sun's limb in lines parallel and perpendicular to the equator, its true place with reſpect to the Sun's center may be accurately aſcertained during any part of its tranſit over the Sun's diſk; and conſequently its neareſt approach to the Sun's center and the time of the ecliptic conjunction may be deduced with great exactneſs, although the middle of the tranſit ſhould not be ſeen, and the Sun ſhould be viſible only for a ſmall ſpace of time ſufficient for taking theſe obſervations.

The following order of making the ſeveral obſervations with Dollond's micrometer in the late tranſit of Venus was recommended to the obſervers who went on the part of the Royal Society to the North Cape and to the South Sea, which may ſerve to elucidate their obſervations. See Phil. Tranſ. Vol. LIX. p. 266, 267. and this Vol. LXI. p. 397, 418

Inſtructions

Inſtructions to the like effect were alſo given to the other obſervers, ſent by the Royal Society to Hudſon's Bay and the North of Ireland, on the ſame occaſion. See Phil. Tranſ. Vol. LIX. p. 480—482. and Vol. LX. p. 488.

" 1ſt, Immediately after the firſt internal contact, " you are to obſerve ſeveral diameters of Venus " (ſuppoſe 12) with 0 of the vernier placed al- " ternately to the right and left hand of the be- " ginning of the diviſions of the ſcale.

" 2dly, You are to obſerve ſeveral differences of de- " clination of the northern limbs of the Sun and " Venus, and the ſouthern limbs of the Sun and " Venus alternately.

" 3dly, If there be conſiderable time left before the " middle of the tranſit, you are to obſerve diſ- " tances of Venus from the Sun's limb to the " eaſt and weſt alternately, in lines parallel to the " equator.

" 4thly, If there ſtill remain conſiderable time be- " fore the middle of the tranſit, you are to ob- " ſerve ſeveral times the horizontal diameter of " the Sun.

" 5thly, You are to begin at leaſt half an hour (an " hour would be better) before the middle of the " tranſit, to meaſure the neareſt diſtance of Venus " from the Sun's limb, and the fartheſt diſtance " of Venus from the Sun's limb, alternately.

" N. B. The ſame poſition of the micrometer " will ſerve for both, without turning it " about. Theſe obſervations are to be con- " tinued till the very middle of the tranſit,

" when the diſtance will continue the ſame
" for a little ſpace of time; but it will be
" better to continue them for ſome time
" longer.

" 6thly, The ſame obſervations which were taken
" before the middle of the tranſit, or ſuch as could
" not, through ſome impediment, be obſerved
" before, may be proper to be obſerved after the
" middle of the tranſit.

" 7thly, It will be adviſeable to practiſe obſervations
" ſimilar to thoſe here recommended, previous to
" the tranſit of Venus, by means of ſpots in the
" Sun."